

1 Formation and Terms of Reference

We were appointed by the Electronics Research Council* in December, 1964, following a recommendation by its Working Party on Solid State Devices, with the following terms of reference:

- 1 To examine and consider the functions of the Establishments of the Ministry of Aviation in ensuring that the special knowledge of their scientific staff is made available to students in higher education in physics, electronics and related subjects, both through instruction given by them at Universities, by secondment of Ministry of Aviation staff to Universities, and through the work of students in the Establishments.
- 2 To examine and consider the role of the Universities in ensuring that students receive education which will fit them for work in research, development and production in those branches of physics, electronics and related subjects of concern to the Establishments of the Ministry of Aviation.
- 3 To make such recommendations as they consider to be necessary.
- 4 To report to the Electronics Research Council.

2 Membership

Professor Sir Nevill Mott, M.A., D.Sc., F.INST.P., F.R.S. (Chairman).

E. Eastwood, Esq., M.Sc., Ph.D., M.I.E.E.

Professor E. W. J. Mitchell, M.Sc., Ph.D., F.INST.P.

C. M. Lock, Esq., M.A. (Secretary).

Procedure

We have held three meetings in addition to visiting a number of Establishments and other institutions (Appendix A) and received information from many individuals; the names of these institutions and individuals are set out in Appendix B and we are most grateful for their help. We have also noted paragraphs 401, 403 and 404 of the Robbins Report, setting out the case for co-operation between Establishments and places of higher education; these paragraphs are reproduced in Appendix C. Moreover we have had before us the letter dated 20th October, 1964 from the Chairman of the University Grants Committee to Vice-Chancellors setting out the advantages of co-operation with Establishments, and the summary of replies (Appendix D) shows that these advantages are recognised and co-operation is already considerable.

3 Relationship with other bodies

Both so that our report could be available without delay to other bodies who are at present considering aspects of the educational structure of this country and so that our recommendations should be before the Minister of Aviation during the present defence review, we have thought it wise to present our report as soon as possible, without making all the visits that might otherwise have been desirable. We have had in mind the questions which arose out of the Report to the Electronics Research Council of the Working Party on Solid State Devices. The relevant recommendations of this Working Party were the following:

* The Electronics Research Council is an independent body of leading scientists and industrialists which advises the Minister of Aviation on research in electronics.

Higher education in the applied solid state field should be stimulated.

In particular:

- (a) The Electronics Research Council should initiate the setting-up of a working party to examine the educational role of the Establishments.
- (b) The possibility should be explored of establishing viable applied research units at selected universities in order to provide incentives and opportunities for a few university departments to contribute in the field of solid state devices and to encourage students and post-graduates to make careers in the application of solid state physics to industry.

Apart from this the most important general conclusion of that Working Party was that the Establishments could and should play a greater role in helping civil developments in the electronics industry. We have therefore considered the most important part of our task to be an examination of the ways in which the Establishments could best help to promote education which would fit students for work in research, development and production in the civil as well as the military sectors of electronic science, particularly with a view to aiding the economy of the country on which all defence activities depend.

4 The need for technological education—The 'Master Technologist'

With the economy of the country in mind, as well as its defence commitments, we first wish to state as forcefully as we can the case why Establishments—and for that matter Industry—have an important role to play in education. During our visits we heard the view expressed that the Universities are the places for education and that the Establishments have their own tasks to fulfil. Our discussions have tended to cover some aspects of Industry as well as Establishments and the same view could be expressed as emphatically by the science based industries; their job is to design, make and sell and their role in education, though often large, must be closely related to the needs of the particular firm. The members of the Working Party strongly take the view that the Establishments and Industry have, in the national interest, a wider educational role, for the following reasons. The Universities, with the courses leading to the B.Sc. and Ph.D. in physics and related subjects, doubtless provide a first class training for the men who will maintain the outstanding tradition of this country in fundamental research. In technology, however, most firms recognise that science or engineering graduates entering Industry from the Universities need further training before they can start to be effective. The simplest evidence of this recognition is the existence in larger firms of graduate apprenticeship schemes and of institutions such as the Marconi College. The purpose of the additional training is to introduce the graduate to characteristics of technology in the real world of which universities have little direct experience. For example, the technologist in producing a design (in whatever field: quantum electronics applied to night vision; communication systems; power production; solid state device production) has to make non-scientific compromises in addition to the scientific compromises which he may have been taught to make. The non-scientific compromises may be forced by the lack of time, money, or materials with the appropriate properties. Only firms or Establishments responsible for meeting real needs can provide the appropriate training because they are the only places where the problem has of necessity to be faced. In university research (science or engineering) if the appropriate

time, money and materials are not available the problem can be dropped or shelved and something else taken up. The attitude of mind engendered by economic necessity is not present. Therefore, by their respective natures, we conclude that the Universities alone cannot provide the additional training and that centres of technology can and must.

It has been pointed out by Lord Bowden that the concept of additional training as a part of the training of the 'whole technologist' is common practice in medicine. It is accepted that a man has to have experience in a centre where the 'technology' is actively pursued—the hospital. Furthermore, the universities recognize this as a requirement for their award of a medical degree. It is this principle which we think should be more systematically applied in technology. The task of hospitals is to cure the sick and repair the injured—the hospitals do not claim that the urgencies of the task preclude their playing an educational role; nor is there any reason for centres responsible for technological development to make this claim.

We believe that the training in the University lasting three years and in a technology centre (Industry or Establishment) for one year are complementary parts of the training of the whole, or master, technologist. If this is so, one might ask whether the whole (or Master) technologist is not the proper recipient of the degree or certificate which classes him as such, rather than the partially trained man with university experience only. Graduates who pursue only a university course are to be thought of as medical students starting to practise after three years of non-clinical training. We would assert this notwithstanding the close contacts with industry that many university science and engineering departments have built up. Naturally such contacts should be encouraged in every possible way, and our report recommends some ways in which this could be done. But however close they are, we believe that the education of the technologist should be partly the responsibility of professional teachers in higher education and partly the responsibility of people whose main occupation is the practice of technology.

The position is of course different when industrial training is part of a sandwich course lasting four years which gives the kind of qualification we recommend. Perhaps the proposed title of Chartered Engineer will have a desirable influence in this direction.

The Working Party believes then that its most important task should be to consider whether the Establishments could and should take part in the education of the properly trained man whom we have called the Master Technologist.

5 The need for economy in the use of scientific man-power

There are other aspects of considerable importance that we have considered. There is first of all the question of economy in the use of scientific manpower. The expenditure on science in government establishments is certainly greater than that in the Universities and in consequence the Establishments contain a high proportion of our most talented scientists. Some members of Establishments now do a little teaching. Would an increase in their teaching duties result in any comparable saving of manpower at the Universities—without detracting from or even, as some members of Establishments have suggested to us, with some stimulus to the proper work of the Establishments? If this is

so, would it be best achieved by (a) secondment for considerable periods, say a year, (b) by giving some members of the Establishments part-time positions in Universities, or (c) by leaving it to personal initiative as at present? Moreover, the staff at the Establishments possess special knowledge and skills not always available to university teachers. Is it desirable on these grounds that their services should be available for undergraduates or post-graduate instruction?

We have also had in mind the rapidly increasing cost of university research. University teachers are believed normally to spend 50 per cent of their time on research and with the increase in the number of university teachers and in the cost of equipment, the total cost will increase rapidly. Would some of this research contribute more to the national well-being and be both cheaper and more significant if carried out in Establishments?

The Working Party has also considered the contribution of the Establishments towards providing the industrial element of sandwich courses, a major contribution that they already make towards the production of well trained technologists; it has also considered their contribution towards the training of students reading for a PH.D., and other aspects of their relationship with Universities.

6 Contribution of Establishment Staff to formal teaching; comparison with the position in the Netherlands

We have found that in the United Kingdom the contribution of Establishment staff to undergraduate teaching is small. We have heard examples of a few special lectures in universities being given, but the general impression in both Universities and Establishments is that the three year undergraduate course is too short and too closely integrated for people who do not spend most of their time in the University to take any major part in it. Also Universities feel that their staff in any one institution should have all the specialist knowledge necessary for an undergraduate course. This would not necessarily apply to post-graduate courses.

For these reasons, being aware of the use made in Holland (as in other Continental countries) of part-time professors, whose main job was in industry or government service, we were fortunate to be able to visit the Technical Universities at Delft and at Eindhoven and to find out at first hand what teaching duties the part-time professors have there. We found the contrast between their situation and ours of great importance for our investigation, and have set it down here in some detail.

In the first place, it must be emphasized that the course in these universities extends over five years and that students often take longer. (In fact some members of the staff of these universities were concerned about the time which students take and the lack of any procedure for requiring them to leave, and were changing the course of instruction every five years to provide an incentive not to take too long). Students would not normally have done any calculus at school, the language requirements at Dutch schools precluding the specialisation in science and mathematics which is usual in England for pupils wishing to read science or engineering at the university. The first year of the five-year course, therefore, was in some ways comparable with the final year in our sixth form, though it perhaps went a little further. It was felt that the pressure

on the students was very considerable. The next three years were broadly comparable with university courses in the United Kingdom, whereas the fifth and final year contained a project. The universities regarded it as their job not only to teach students how to do research but also to convey some of the features of development work and projects were frequently chosen with this in mind. Some were of an advanced nature and a succession of students might work on the same project. Staff known as 'scientific collaborators' with no lecturing duties acted as research tutors to these fifth year students. Examples of projects seen in the physics laboratories were:

- (i) Adiabatic demagnetisation using the anisotropic nuclear paramagnetism of Ce Mg Nitrate; it was hoped to reach 10^{-5} °K.
- (ii) Effect of plastic deformation (introduction of dislocations) on Young's modulus, critical temperature and other low temperature properties of metals such as Cu, Au, Al and Ag.

In electronics, projects included systems engineering as, for example, the computer control of lifts. Our host at Delft, Professor Kröning, made a very important point, namely that the technical university did not attempt to retain the best students for research after they had graduated. It was regarded as the duty of the university to provide the best men for industry.

We enquired in detail about part-time staff. The University of Delft had 50 part-time professors out of a total of 175 professors. The part-time professors spent 1 to $1\frac{1}{2}$ days per week at the university, and, since they did not take a full share of the administrative load, there was a maximum number which could be carried without overloading the permanent staff with administration. Part-time staff were advisory, but not voting, members of the University Senate and took part in departmental meetings. The normal tenure of a part-time chair was three years; this allowed flexibility in coping with changes in the relative importance of different subjects. Payment was made by the university; it was in addition to the industrial salary and was usually scaled in proportion to the amount of time involved.

The main advantages of the employment of part-time staff were that they promoted close contacts between universities and industry, which was considered very important in Holland, and that they had the ability to teach new technological subjects for which full-time staff might not be available. Industry in Holland was sympathetic to these part-time appointments which were considered to offer a certain distinction. The procedure for establishing a chair was the same as for a full-time appointment; approval by the Ministry of Education was needed and the selected person would be formally invited.

The non-technical universities also used part-time appointments in subjects such as medicine, law and theology. Two men from Shell and two from TNO (the Dutch equivalent to our former D S I R) had appointments in Leiden.

The teaching responsibility of part-time professors was for the main part specialised in nature and confined to the later parts, and in particular to the final year, of the university course. Part-time professors could be responsible for projects and sometimes a project was carried out in the part-time professor's industrial or government laboratory. This did not seem to happen in Philips but we heard instances of it in the Technical Physics Department of

TNO. We were struck by the fact that, apart from the thesis and oral examination, separate examinations during a student's time at the University were held on each course. This perhaps simplified the use of part-time staff who were enabled to examine on their own speciality without being concerned unduly with the whole educational process.

At Eindhoven, where the new Technological University and the Philips laboratories are in close proximity, we found perhaps less anxiety to build up a close relationship than at Delft. The University was planning that most of the project work should be done within the walls of the university rather than in Philips. We learned that Philips themselves, while welcoming students in their own laboratories, were in general accord with this situation, feeling that since the role of the Universities was primarily educational, the proportion of project work there was about right and that the Universities' direct contributions to technology were not great.

Our conclusion from this visit was that part-time professors played an important role in Holland, but that their role was not great in what we call undergraduate teaching and it would be even more difficult to introduce them here in this context owing to our different examination system. Our visit to Holland reinforced our belief that it is in terms of a fourth year with a strong technological bias that we ought to consider the extension of the teaching duties of members of Establishments, beyond their present contribution in providing the industrial sandwich element for students taking sandwich courses.

7 The present position in the United Kingdom

7.1 *Teaching by Establishment staff at Universities*

We have found that several Establishments (not only those of the Ministry of Aviation) are providing staff for teaching in regular courses. The main examples which have come to our notice are the relationship between the University of Strathclyde and the National Engineering Laboratory, and that between the Manchester College of Science and Technology and the Atomic Energy Authority, and between the Atomic Energy Authority's Culham Laboratory and the University of Oxford.

Many establishment staff are well qualified to give either special or general lectures at post-graduate level at Universities. This is arranged at present in two alternative ways. For occasional specialist lectures which arise directly from the work of the Establishment, staff may be regarded to be on outside duty, have their expenses paid, enabled to use Establishment facilities for the preparation of their material and then the whole cost, including salary and expenses, is to be recovered from the University. Alternatively, staff may wish to undertake lectures on a private basis, in which case they take time off from their allowance of annual leave and prepare their material in their own time. Fees are then payable to the individual. In a recent example of the latter kind, four members of R.R.E. staff undertook to give a course of sixty lectures at post-graduate level in theoretical physics at Birmingham University to fill a temporary gap caused by changes in the University staff. Many similar cases can be quoted. Staff are said to enjoy a limited amount of teaching in subjects in which they are interested and loss of annual leave is compensated by the fees paid. This is a very different matter, however, from the undertaking of a general teaching commitment as part of one's employment. We have to ask whether it is desirable that the staff of Establishments should do this as a

routine matter in subjects not directly arising from the work of the Establishment. We are unable to recommend this; we believe that Universities should be properly staffed to do their job and priorities assigned in the distribution of scientific manpower so that for routine teaching they do not have to call on Establishments. Nonetheless it should be easier for heads of establishments to authorise some teaching as an outside duty when it seems to be in the interests of the Establishment or of the individual concerned, both for bringing Universities into contact with their work, to aid recruitment or for any other reason. Certainly it seems to us that the arrangements whereby staff undertake teaching in their own time, either for payment or otherwise, are satisfactory, except for the limitation imposed by the necessity to do this work during an officer's annual leave. But the arrangements whereby teaching is done during an officer's working time and paid for by the Establishment require clarification, both as regards the conditions under which this may be done and as regards the overall resources which may be devoted to such work. We recommend that the head of the Establishment should have considerable discretion in such matters.

These remarks refer to occasional teaching which an officer may usefully undertake for one reason or another. On the other hand we recommend a much more definite policy in respect of teaching which is related to the major technological programme of the Establishment. As we have already suggested in Section 4, just as a hospital must assume responsibility for the training of doctors, so any centre taking a leading part in technological development must assume part of the responsibility for training the men that the technology will need. This should be done by Establishments both in sandwich courses and also at the postgraduate level, in courses of any appropriate length. We hope that the financial disincentives to doing such work can be removed and we strongly recommend the Establishments should have a definite mandate to teach in these fields. We consider that Establishments should be allowed to spend a certain proportion of their budget in this way, perhaps as much as 10 per cent, in certain fields on this kind of educational activity. We shall return to this theme in Section 9 of our report.

7.2 Secondment for long periods

Unpaid leave on approved employment terms (which means retention of pension rights) may be granted to Civil Servants for up to three years to enable them to take up teaching appointments at Universities. Perhaps the most impressive case among officers of the Ministry of Aviation is that of D. A. Spence, a merit S.P.S.O. from R.A.E., to become a Lecturer and Fellow of Lincoln College, Oxford, but there are several similar examples in recent years. We support this activity as a proper and valuable aspect of essential interchange between Universities and Establishments.

7.3 Sandwich Courses

The Ministry of Aviation operated the Diploma of Technology Scheme from its inception in 1956 both in Engineering and Applied Physics and Mathematics and assisted in planning the courses. The Ministry of Aviation's annual intake in Applied Science is limited by Treasury ruling to 20; in Engineering the number is reviewed annually. We understand that experience has confirmed the success of the thin sandwich variety of degree course, which results in a mature, well balanced product. Candidates for courses have to attain

acceptable results at 'A' level and a good marking at an interview board upon which colleges are represented.

At present there are 70 students taking the course, comprising 61 in Physics and 9 in Applied Mathematics. So far 62 Ministry of Aviation and 8 Ministry of Defence students have completed the course, with the following results: — Failures 2, Passes 20, Honours 48, Appointed Scientific Officer 25 (8 others are still under consideration). Some of the honours graduates have proceeded to research appointments to work for higher degrees. On the Engineering side there are currently 69 students and the results achieved have been about the same as in Physics and Applied Mathematics. In this case however there is no binding agreement for the graduates to take employment with the Ministry.

The cost to the Ministry of Aviation is £350-400 per annum for each student. In addition to the works-based students mentioned above, there are in the Establishments an approximately equal number of college-based students, who include Chemists. Students are held on headquarters complement so that their effort in the Establishments' laboratories is additional to that of the regular staff.

7.4 Contribution to the training of PH.D. students

The system under which work for a PH.D. under the supervision either of a university teacher or establishment officer can be carried out partly in an establishment is occasionally used, and in general university regulations do not prevent it. Thus Cambridge demands that a Cambridge graduate spends only one out of his three years in residence or a graduate of another university two. (Cf Appendix D).

The Working Party sees arguments against too wide a development of this practice. Universities have the main responsibility for fundamental research in this country. Through being able to obtain good facilities for research, they can attract and keep university staff of high calibre, their work brings prestige and sometimes economic advantage and is of great stimulation to advanced teaching. Research students are essential to university research schools; it is they who, under direction, do much of the research. The research schools would be greatly impoverished if a high proportion went elsewhere for their first experience of research. Moreover undergraduate teaching would be hindered by the absence of research students, who help with practical classes and in other ways. The Universities will probably feel that the PH.D. of a given university should be given for the particular kind of training in research offered by that university.

The Working Party thinks then that the regulations under which students registered for a PH.D. at a given university can work in an Establishment should be liberal, but that the essential point is that the student should remain under the supervision of a member of the university's staff or at any rate should be sent there on the initiative of the professor.

7.5 Conditions under which Universities award PH.D.'S to scientific officers in Establishments

The University of London allows its graduates to enter work done at Establishments or elsewhere for the PH.D.; this privilege is not accorded to their graduates by most other universities. Many people to whom we have spoken have commented on this and our views have been asked. We do not feel that

this question is directly related to the educational role of the Establishments and we would feel it outside our terms of reference either to advise London to come into line with other universities or to recommend the reverse. We have however some sympathy with that opinion in universities which is reluctant to see them award degrees (other than D.Sc. or Sc.D.) for work over which they have no control. Universities, particularly those outside Oxford and Cambridge, are under great pressure to accept local and even national responsibility for many activities, e.g. for teacher training, and in the opinion of many they have to be very careful about this if they are to continue effectively to perform their proper role. We doubt if Universities should be under pressure to accept as Ph.D. students young men who are *de facto* members of the staff of Establishments or who hold research fellowships there. We realise that increased facilities for taking the Ph.D. are strongly desired by some members of Establishments and of industrial laboratories. We cannot help asking, however, whether the effect of extending these facilities would not be to put pressure on the Directors of Establishments and of industrial laboratories to allow an undue number of their staff to undertake the kind of fundamental research which could be published and presented for a degree rather than the bread-and-butter or technological work which are the real *raison d'être* of the laboratory. But we realise the situation created by the policy of London University does give rise to a sense of unfairness.

If the Establishments feel a need for a degree or diploma for scientific officers whose work is not closely connected with that of a University the matter seems to us one between the Establishments and the National Council for Academic Awards. Yet if this facility were developed it would be essential that the National Council for Academic Awards should reward with a degree of comparable standing work of the kind which is not normally published and which is directed to the production of hardware and other short-term aims of the Establishment.

7.6 Research by University staff in Establishments

We have not found examples of university teaching officers actually doing their research, along with their research students, wholly or mainly in Government Establishments (or industry), except as part of government sponsored research agreements. As far as we can see, this practice occurs only when scarce national facilities exist (e.g. reactors, accelerators for nuclear physics) but the kind of research done in the Metallurgy Division of R.A.E. or the Physics Department of R.R.E. would be entirely suitable.

The advantages of encouraging (not compelling) such developments are that while everything should be done to give proper facilities for outstanding research teams in universities (and many others not quite so eminent doing first class research), it can be argued that with the very rapid increase in the cost of university research and—particularly with the CATs—the large increase in the number of university teachers wishing to supervise research students (leading to growth rates in the past of 11-12% in real cost per year), it would be in the national interest if some of this effort could be harnessed to projects satisfying the direct needs of Industry and of the Establishments. This harnessing could be better and more economically achieved by work in the Establishments (or Industry) than by the university teacher going there and looking for problems to work on in his own laboratory.

The reasons why it does not happen are clearly:

(a) Distance between the Establishment and the University.

or

(b) The natural desire of the university professor to 'have his own show'.

or

(c) The lack of guarantee of crucial facilities on a regular basis.*

We believe that this kind of co-operation should be encouraged and would also develop more naturally if there was an expansion of the activities of the Establishments in teaching in sandwich courses. This would bring the staff from the University concerned more frequently into the Establishments, the more so the closer they are to each other. The Working Party was impressed during a visit to Marconi College with the great effort which the teaching staff made there to keep in contact with the real needs of the Company (English Electric), an effort which took the place of individual research as practised in many other teaching institutions.

One of the simplest ways of achieving this kind of exchange is through the medium of extramural research agreements which provide an administrative basis for the interchange of staff and facilities. Under the agreements the University effectively undertakes a convenient part of the Establishment programme and in this context we note with approval the policy of S.R.D.E. to insist that post-graduate students so employed should spend some weeks at least inside the Establishment so as to become thoroughly familiar with the aims of the related programme. Given sufficient support this activity can lead to a useful and productive working relationship. There is an added advantage when there is a grouping of agreements, not necessarily all for one Establishment, giving some coherence of purpose and continuity as, for example, the work on ionic crystals at Aberdeen, on electronic materials and on active aerials at Birmingham or on lasers and their applications at Southampton. We believe that the employment on research agreements of more senior staff, that is of post-doctoral as opposed to or in association with post-graduate workers at the University is a further factor to be encouraged.

Steps should be taken by the Science Research Council to encourage universities, perhaps particularly the former CATs, to build up research interests similar to those of neighbouring establishments. Something of the kind may become necessary in view of the expected increase in the number of university teachers, the increasing cost per research worker and the budgetary limitations likely to be imposed. We suggest that the sub-committees of the S.R.C., when receiving applications for grants from universities or colleges with reasonable access to Establishments, should point out that facilities exist there and (we hope) can be made available and that financial support for research is not likely to be generous unless the committee is satisfied that a reasonable degree of co-operation exists. Even at present a new university is not likely to receive grants for equipment in an expensive branch of science such as nuclear physics. It may well be asked to make use of national facilities. We recommend that the Ministry of Aviation should discuss with the S.R.C. the implementation of a similar policy in the cases which we have in mind here such as is

* Although we understand that a very happy working arrangement has grown up between S.R.D.E. and a Lecturer in the Department of Natural Philosophy of Aberdeen University.

already done of necessity in Space Research. We would even go so far as to suggest that universities, before appointing men to chairs in scientific and technological subjects, should discuss with the S.R.C. in appropriate cases the support that is likely to be given for building up a new and independent group and the attitude to co-operation with neighbouring Establishments.

A list of Establishments which are near to Universities is attached as Appendix E.

7.7 Postgraduate courses

Apart from the industrial element of sandwich courses, the major contribution of Establishments to education at the present time is to postgraduate courses. It is here that the special expertise of members of Establishments is most used to supplement that of university staff, both in teaching students attending one year courses and probably to some extent Ph.D. students. The Working Party has, for instance, seen particulars of the courses on materials science being organised by the University of Oxford (Department of Engineering), University of Bristol (Department of Physics) and Bristol College of Advanced Technology (Department of Physics). A course is being planned by the University of Essex on 'Industrial Physics' after wide consultation with industry and with the help of their staff. All these make considerable use of staff from Establishments and Industry. We are clear that the participation of such men in such courses is to be welcomed, both on account of the specialised knowledge that they can add and as being economical of manpower.

Much as we desire the development of the teaching duties of Establishments, we cannot help being critical of some university-based postgraduate courses. We have to ask—do they contribute to the education of the master technologist as we have defined it, and how do they compare with the kind of education given to graduates in industry, for instance at the Marconi College? Or are they meant for the weaker student to enable him to assimilate the material put before him during his undergraduate course or what is the purpose?

The Department of Education and Science has just completed an enquiry into longer-term postgraduate courses for Engineers and Technologists (the Arthur Report). While many such courses are probably most valuable, certain findings arise which are disturbing to us:

- (a) Certain universities and colleges had tried to start courses but had failed to attract students.
- (b) The average number of students per course was 8, of which 45% (59% in the CATs) were from overseas.
- (c) The great majority of such courses were started on the initiative of universities and colleges. Only in a few cases was the proposal made by a firm or organisation. Employers were said to give little support and take little interest. Only occasional use was made of lecturers from industry, industrial research centres or government departments. There are however some notable exceptions.*

* (p. 22 of Arthur Report). 'There are some notable exceptions to the state of affairs outlined above. Some university departments make great efforts to bridge this gulf and seek to establish close contacts with particular firms and organisations and particularly with industrial and government research centres. They try to diagnose the needs of sections of industry and are in a position to mount helpful postgraduate courses, sometimes with the assistance of staff from research centres and from industry. They usually find it difficult to get the first few students from industry, but when the course is found useful the numbers rise in successive years.'

It is our unanimous view that postgraduate courses should normally be organised with the intention of fitting a student for a definite career. If organised in universities for students going on to a Ph.D. and a career of research in universities or elsewhere, in physics or electronics, they will normally be given by university staff, though the participation of Establishment scientists, particularly those engaged on fundamental research, will be helpful to both sides and economical of manpower. But if organised for any other purpose, e.g. as training for productive industry or for service in Establishments, it should be asked whether Industry or Establishments could not do the job better.

Here it is relevant to consider the function of the Marconi College which serves the English Electric Group of Companies and which may be used as an example of the methods of a major industrial complex to provide the special technical education it requires.

The College takes about 100 students each year who are grouped as Student (40%) or Graduate (60%) Apprentices and who take a sandwich course over several years which equips them for entry into one of the divisions of the English Electric Group. The Staff of the College themselves do no research but may spend nearly half of their time keeping up with their subjects by means of visits to the parent laboratories and elsewhere. Nearby universities and technical colleges collaborate in the student courses.

The College of Electronics at Malvern, which is part of the R.R.E., performs a similar function for the Ministry of Aviation but with important differences. Here the division is into Craft Apprentices (about 40 per annum) of whom about half remain subsequently in the Ministry of Aviation for more than two years and Student Apprentices (about 24 per annum). At present, about a third of the latter who finish up with either H.N.C. or Grad. I.E.E. enter the Service in either the Experimental or Engineer Classes. In their final years the Grad. I.E.E. student apprentices undertake, frequently in collaboration with the laboratories of R.R.E. and under the joint supervision of the R.R.E. and College staff, research projects of an advanced nature.

We return to the theme of Establishment-based technological education later in the report in Paragraph 10.

8 Location of Establishments near institutes of higher education

The case for propinquity was made by one of us (NFM) in a letter some years ago to the Universities Quarterly, and in evidence submitted to the Robbins Committee. Evidence was also submitted by Dr. B. V. (now Lord) Bowden in this sense. The Robbins Report says on this 'Some of our witnesses have suggested that certain research establishments might form the nuclei of new universities. We do not think this desirable, for experience in the United States suggests there may be danger for an educational institution that subordinates its needs to those of a dominant research centre.' (p. 134).

The Working Party agrees that no existing Ministry of Aviation establishment could properly form the basis of an institution of higher education. On the other hand, as we have stated many times in this report, any establishment, industry or other concern which plays an important part in the economy of the country, or any other important activity (e.g. defence) has an educational role. It can play this part best in co-operation with a university or technical college

of some kind. Therefore there is every advantage in propinquity, and we believe that this should be taken into account in siting new colleges or establishments.

It seems that plans are in hand to establish special relationships between Establishments and neighbouring Universities, so that by the interchange of staff, equipment, laboratory facilities and lectures, a measure of interdependence and mutual stimulation may be set up. Examples of this are the proposed relationship between Birmingham University and R.R.E. Malvern and between Southampton University and S.R.D.E. Christchurch. No doubt similar arrangements may come into being between R.A.E. Farnborough and the new University of Surrey.

In this context the Working Party notes with some interest the tendency of establishments, for example, S.R.D.E., to provide members of their own staff on detached duty to work at universities on research agreements for which the funds are supplied by the Ministry of Aviation.

In America it is not uncommon for a special relationship to be established between an industrial laboratory and a neighbouring university. The Oak Ridge National Laboratory, for example, entertains some sixty faculty members each summer from the University of Tennessee, while individuals from the University can spend some three to twelve months in the Oak Ridge Laboratories each year. In return, the University operates a Resident Graduate Scheme at Oak Ridge. The Oak Ridge National Laboratory staff give some two hundred lectures or Seminars each year in the universities. On the other hand, the relations between the State University of New York and the Brookhaven National Laboratory are not so interdependent, it being considered desirable for the University to staff its own programme, apart from exceptional specialist lectures.

Similarly, the relationship between the Massachusetts Institute of Technology and the Lincoln Laboratory is not as close as might be expected, probably because both of these great institutions are large enough to be independent. The Lincoln Laboratory does not make a great contribution to the teaching programme of M.I.T., but does entertain about a dozen post-graduate students each year, supervised and visited by a professor from M.I.T.

We appreciate that in the U.K. the foundation of further new universities is unlikely to be considered for some years, nevertheless we wish to draw attention to the advantages of propinquity (for example a University of Bournemouth would be well situated with regard to S.R.D.E., M.E.X.E., A.M.L., Winfrith and Portland) and of participation by Establishment staff in the management and decision-making of the Universities with which they are involved.*

**Regional and area colleges*

It may well be that it is with regional and area colleges as well as a few technological universities that the Establishments can most usefully co-operate. The Association of Teachers in Technical Colleges has just issued a report 'The Future of Higher Education within the Further Education System'. The following quotation from it is interesting

'There are two separate and distinct traditions in English higher education. One concentrates upon the full-time degree course planned on the basis of learning for learning's sake. The assumption is that the student's motivation is primarily his interest in his subject and although the content of degree courses has been expanded in recent years to a point where the student is seldom able to depart far from the

Finally, in this context, it is relevant to note that the Electronics Research Council and its Committees and Sub-Committees provide a means whereby leading members of the Universities and of Industry are invited to discuss and advise upon the research programme of the Establishments.

9 The most important teaching role of the Establishments

Much that we have already said leads to the recommendation which we consider the most important part of our report. The Establishments can contribute usefully but peripherally to academic higher education, and we hope that they will continue and expand these activities. But their real role in the interests both of defence and of the economy should be to contribute to the training of men in those branches of technology in which they are eminent. They share this duty with industry. It is widely felt, and not only among scientists and engineers, that those outside the professions of teaching and basic research should take more part in the education of our young people. The following quotation from a review (by the Chaplain of the University of Sussex) of a book by Mr. Frank Musgrove is typical:

"The educational process seems to become progressively longer and more and more people are involved in it. We are, in fact, rapidly approaching a situation in which the academic community becomes the determinative influence in shaping the lives of most of our young people who show any potentiality for leadership. Mr. Musgrove is right in calling attention to the fact that this community is not well equipped in all respects to perform this function and that its limitations should be clearly realized. "Those who can, do; those who can't, teach" is an oversimplification which our society has rightly rejected, but an academic community whose character is largely set by teachers and research workers is not necessarily an ideal school of maturity for those who have to take decisions in the everyday world. The academic virtues are essential to the well-being of modern society but they flourish best when those who aspire to them are not excessively segregated from the rest of mankind."

And Professor Armytage (Professor of Education, Sheffield) advocates strongly the 'University of Scunthorpe'—a university in contact with the dirtier kinds of industry rather than cathedral cities. More concrete criticisms are to be found in the Feilden Report on Engineering Design with its stricture on engineering courses based on (university) research rather than design. In the House of Commons debate on this report (Hansard, 19th March, 1965, p.1723), Mr. Bishop said:

syllabus laid down, the underlying philosophy is that knowledge should be followed wherever it leads, irrespective of whether it proves to have any applicability to the affairs of the world outside the academic enclave. The manner in which the student will subsequently earn his living is not the primary concern. Indeed in many cases he is advised to postpone his choice of career until he has taken his degree, so that he may make his decision in the light of the intellectual maturity that results from three years' full-time study at this level.

"In the other tradition of higher education courses are of varying length and are both full and part-time. The underlying assumption is that the student's primary motivation is the profession he intends to follow. He is committed to a profession from the outset and his course of study is closely integrated with his professional work. He is given direct experience of professional practice at an early stage in his course and is enabled to see his studies against the background of what his profession requires. He and the staff who teach him maintain close contact with the profession and, as a rule, many of his teachers have themselves spent time practising the professional occupation for which they are preparing him.

"In this country the universities have tended to follow the first tradition and the technical colleges the second. The distinction has not been absolute.'

'Provision ought to be made for far more young people in our schools and colleges, whatever course of education they may be undertaking, to spend some time in contact with technical matters and so develop a greater appreciation of their importance. . . . In education, university and school courses should include several months of experience in industry so that our young people may know what the job really means and what it is all about for later when they may decide to enter it.'

Much is being done, as was explained by the Parliamentary Secretary (p. 1734):
'The last of the recommendations of the Feilden Report to which I should like to refer is

"the establishing of institutes at suitable universities and colleges for advanced studies in particular fields of design in close association with industry, and the establishing of a higher degree in engineering design."

Last year, agreement was reached following discussions between the Loughborough College of Technology, industry and the Department of Education and Science on the setting up at the college of a centre for engineering design. . . .

The centre will be for graduate engineers and it is envisaged that its work should aim to incorporate the definition of a designer's responsibility given in the Feilden Report and which

'covers the whole process from conception to the issue of detailed instructions for production. . . .

. . . The University of Cambridge plans to start one-year post-graduate courses in engineering design methods in October, 1965. The course will lead to a Certificate of Advanced Study in Engineering.'

It is in this kind of activity that we hope the Establishments will increasingly join, particularly if this could occur in parallel with an increased role in helping the productive industry of the country on the civil as well as on the military side. The overall aim of any such development must be to attract more talented men towards productive industry and industrial research and development. The difficulty of doing this in industry is that its successful designers and applied scientists can rarely be spared for such teaching. The temptation will always be to use the long-range research worker or people like the staff of Marconi College who wish to make teaching their full-time career. To use an expression put to us by the education officer of one firm, the people in industry who have something unique to contribute are those 'close to the hot breath of the customer' and these cannot be spared. It is possible that the Establishments, not being subject to the commercial pressures of competitive industry, could undertake this duty more easily, notwithstanding the high importance and urgency of some of their work.

As we have said, we believe that, particularly for students whose education has not included a sandwich element, a fourth year or more is essential to the development of the thoroughly trained technologist and is often provided in industry by the larger firms. The Establishments can make a major contribution to this particularly as they develop their co-operation with industry themselves, especially with individual firms. As we have said, we believe that as such a role develops the Establishments, in co-operation with suitable institutions of higher education, should take a major part in working out courses of postgraduate education in which a limited number of highly qualified young

men would receive a training in research, development and design closely linked to a given branch of technology for which there was a national need. It is this role, rather than co-operating in university-based postgraduate courses, that we find the most important role of the Establishments.

We must ask, therefore, how these essential developments are to be encouraged. We see three ways in which it can be done.

(i) The Establishments should have a mandate for teaching, particularly this kind of teaching, as we have already explained in sections 4 and 7.1.

(ii) Establishments should continue to place contracts in universities for research work in fields of interest to them. This too we have discussed. We were particularly interested in the policy explained to one of us by Mr. Sutton, of S.E.R.L., which was to define an objective, civil or military, in which there is considerable activity in a government laboratory and then find one or more university departments with sufficient interest to undertake research relevant to the project. A consortium could then be established consisting of the Government laboratory, the universities concerned and an industrial firm ready to take up any commercial exploitation which may become possible.

We have noted that many Establishments through CVD or otherwise place contracts with Universities to carry out research in fields of interest to them. We fully support these activities and believe they should be extended, particularly when the research is closely co-ordinated with the work of the Establishment and of real help to its technological mission. We believe that through such research the right relationship between the Establishments and the Universities can be built up and that it will greatly aid them to co-operate in developing together the forms of postgraduate education which will provide men fully trained to contribute to branches of technology where the responsibilities of the Establishments lie.

(iii) Certain members of Establishments should be offered part-time teaching positions in Universities. As we have already stated, this is usual in Holland, members of industrial laboratories frequently contributing about one day a week to the work of a university and even taking part in committee work. We understand that such an arrangement exists between the National Engineering Laboratory and the University of Strathclyde and that it has been proposed between the University of Birmingham and R.R.E. We believe that such arrangements could be very valuable in building up a spirit of co-operation between Establishments and Universities, and we strongly recommend that they be developed wherever appropriate. We do not feel ourselves competent to recommend on the financial arrangements involved but believe, once it is admitted that the Establishments have a mandate to teach, that they could easily be solved. We think that such arrangements would be particularly valuable if Establishments, in co-operation with Universities, take a leading part in establishing technological courses and recommend that the degree awarded for such courses should be the joint responsibility of a University and an Establishment which have a special relationship with one another involving such part-time teaching appointments.

10 Conclusions

In our examination of their educational role we have found that the staff of the Establishments have considerable interest in various forms of training and that there is no obstacle to their undertaking a limited amount of such work. Bearing in mind that the principal role and appointed task of the Ministry of Aviation is to pursue a programme in support of defence and of civil aviation, we have been impressed by the effort towards education that has been made within the present mandate. But, as our report has emphasised, it is necessary to make a distinction between general scientific education and training leading to design and development. With regard to the former, we feel that with some encouragement and with the removal of certain obstacles, this work could develop and expand without difficulty. Recruits coming from postgraduate research in the Universities find that the transition to the atmosphere of the government laboratories is easy. Staff in these laboratories are often well qualified and willing to undertake a reasonable amount of lecturing or other teaching as opportunities arise and in practice the administrative system appears able to support this activity with little hardship to the staff involved. We doubt whether the Establishments or the country as a whole would benefit if there were a definite commitment to help the universities with routine teaching, but we were clear that everyone would benefit from the removal of some of the obstacles of all kinds to teaching which still exist.

With regard to the project side, including work on design and development, the position is less satisfactory. Here the immediate task is the successful completion of a programme within a timetable, and educational activities may compete with rather than complement the principal work of the staff involved. We have had to consider, therefore, whether a broadening of the mandate, at perhaps some cost to the immediate prosecution of the short term programmes, would result in an increased benefit in the long term to the objectives of the Ministry of Aviation and the industrial strength of the country. This we believe to be the case. We consider it essential that those engaged in research and development should assume the duty of contributing to the education of the young men who will work in the fields in which they are engaged. We believe that without clear recognition of this, and without a mandate written into the terms of reference under which the Establishments work, there is only a limited scope and incentive for this kind of teaching, which may therefore be regarded by some as an unwelcome diversion from the principal task.

In the area of applications or projects or where the Establishments have a strong commitment to the applied research to meet urgent requirements for equipment there may be great pressure on staff to concentrate on the programme to the exclusion of educational activities. And yet it is on this side that there seems to be the experience whose lack is most felt in the training of technologists. The problem is to ensure that education has the right place in the list of priorities as it has in the teaching hospitals of the medical service.

We are far from believing that the Establishments should undertake such education on their own without the co-operation of Universities, regional colleges and other institutions of higher education. We believe that it should be a joint exercise. The problem is therefore not only to remove restrictions on the work of the Establishments, but to build up a spirit of co-operation between Establishments and Universities which would make the exercise easy. We have discussed in the previous section various ways in which this

could be done, namely through research contracts, through the appointment of Establishment staff to part-time positions, through the use of Establishment research facilities by university personnel and so on. We emphasise the desirability of postgraduate courses for students of high calibre in the branches of technology in which the Establishments excel, and recommend that Establishments co-operate with Universities in awarding the diploma or M.Sc. appropriate to such courses.

11 Recommendations

1 It should be accepted that an Establishment responsible for research and development in a given branch of technology must assume a major responsibility for advanced training in this field and for seeing that the educational potential resulting from its own work is properly utilized. It follows that the Ministry of Aviation Establishments should be authorised and expected to devote a proportion of their effort to this end. In particular, Establishments should undertake the training in the fields where their responsibility lies of graduates, as well as sandwich course students. The training should be carried out in co-operation with Universities and Industry but the major part of it may often have to be done within the walls of Establishments.

The following recommendations arise from the broad principles of the first.

2 The Establishments should have a mandate for teaching under three headings;

- (a) Sandwich courses (which they already have).
- (b) Postgraduate training in technology.
- (c) Occasional teaching, for example in postgraduate courses at the universities.

3 The following steps should be taken to increase the degree of co-operation between Establishments and Universities so as to achieve these objectives:

(i) Universities should be encouraged to offer selected members of Establishment staffs part-time teaching positions with responsibilities particularly for postgraduate teaching similar to those in Holland.

(ii) University and technical college staff should be encouraged to make use of research facilities in Establishments and to join in Establishment programmes, and the Ministry of Aviation should discuss with the Science Research Council ways in which to take account of this possibility in allocating research grants, provided that use of the facilities is more or less guaranteed.

(iii) Establishments should continue to place research contracts in universities, particularly for work likely to lead to military or commercial development.

(iv) Special relations between the Establishments and neighbouring Universities should be developed where appropriate and the location of neighbouring research Establishments should be taken into account when starting new universities or colleges, and vice versa.

Finally we think it our duty to stress that these recommendations are in no way affected by any change in the size of the Establishments that may result from a changing defence commitment. We do not regard the educational role of the Establishments as a form of diversification.

December 1965

Appendix A

List of Meetings and Dates

12.11.64 Meeting of Chairman and Secretary to discuss terms of reference.
 20.1.65 First meeting at Castlewood House.
 23.2.65 Visit to Marconi, Chelmsford.
 8.3.65 Visit of Chairman and Professor Mitchell to Harwell.
 9.3.65 Visit of Chairman to Culham.
 18.3.65 } Visit to Delft and Eindhoven.
 19.3.65 }
 26.3.65 Visit to R.A.E. Farnborough.
 28.4.65 Visit to R.R.E. Malvern.
 11.5.65 Visit of Chairman to Manchester College of Science and Technology.
 9.6.65 2nd Meeting at Castlewood House.
 15.7.65 Visit to S.R.D.E. Christchurch.
 30.7.65 Visit of Chairman to Vice-Chancellor of Birmingham University.
 4.8.65 Meeting of Chairman and Mr. R. W. Sutton, C.B., O.B.E., B.Sc.
 6.8.65 Meeting of Chairman and Secretary to discuss draft report.
 31.8.65 Meeting of Chairman with Sir Gordon Sutherland, F.R.S.
 29.9.65 3rd Meeting at Castlewood House.
 12.10.65 Presentation of Report to Electronics Research Council.
 14.12.65 Presentation of Report to the Minister of Aviation.

Appendix B

Institutions and individuals who have contributed information to the Working Party.

The Atomic Energy Authority.
The Delft Technical University.
The Eindhoven Technical University.
The English Electric Group.
The Manchester College of Science and Technology.
The Philips Research Laboratories, Eindhoven.
The University of Birmingham.
The University Grants Committee.

The Ministry of Defence (Navy), (CVD and SERL)

The Establishments of the Ministry of Aviation.

Professor C. Adamson, M.Sc., D.Sc.

Sir Robert Aitken, M.D., D.PHIL., F.R.C.P.

Dr. D. S. Billington, Oak Ridge National Laboratory, Tennessee

James H. Crawford, Oak Ridge National Laboratory, Tennessee

Professor L. R. B. Elton, Battersea CAT (proposed University of Surrey).

Professor M. Federici, University of Genoa.

Thomas F. Irvine, Jr., State University of New York.

Professor R. de L. Krönig, Delft Technical University

Professor M. J. Lighthill, M.A., F.R.S.

Sir Harold Sanders, M.A., PH.D.

Professor R. A. Smith, C.B.E., F.R.S.

Sir Gordon Sutherland, M.A., PH.D., F.R.S.

R. W. Sutton, Esq., C.B., O.B.E., B.Sc.

Dr. F. A. Vick, B.Sc., Ph.D., A.M.I.E.E., F.I.N.S.T.P.

Sir John Wolfenden, C.B.E.

Appendix C

Extracts from the Robbins Report

402 There should be closer co-operation of institutions at university level both with Research Establishments and with industry. Some of our witnesses have suggested that certain research establishments might form the nuclei of new universities. We do not think this desirable, for experience in the United States suggests there may be danger for an educational institution that subordinates its needs to those of a dominant research centre. Nevertheless, we are clear that in Great Britain there is scope for much closer relations with the Research Establishments, especially those maintained by the Government. Closer links are also needed with Industry. Many institutions have hesitated to form such links from a fear that industry might attach strings. There are problems here, but they should not be exaggerated.

403 The complex, and sometimes unique, facilities of the Research Establishments are national assets much too valuable to remain isolated from the educational system. Collaboration is especially needed in fields where there are no comparable facilities in universities or colleges. More research should be carried out by students under the joint supervision of academic staff and the staff of a research establishment: if joint arrangements for supervision are made, it will be possible for work in the establishments to form part of a project leading to a higher degree. The Research Councils and the new machinery of government we propose in Chapter XVII should have a special responsibility to encourage this and other forms of collaboration.

404 There should be much freer movement of staff between higher education, Government Research Establishments and Industry.

Institutions of higher education should invite more part-time assistance in teaching from staff employed in other fields. As we point out in Chap. XII, such part-time help will be especially needed by Universities and Colleges in the period of expansion ahead. Closer contact with education may provide scientists employed in research establishments with new interests and may introduce a possible flexibility into the careers of some whose interests are no longer predominantly in research.

Appendix D

University Grants Committee

Links between the Universities and Research Establishments and Industry

1 Universities were consulted on these matters in two letters from the Chairman of the University Grants Committee (copies of which have already been made available).

2 The general attitude is one of willingness—and indeed anxiety—to collaborate both with research establishments and with industry to the maximum possible extent, for the benefit of both sides. This attitude is fostered by the fact that in a number of cases, there are industrial representatives on the governing bodies of the universities. Similarly, members of the universities take part in the direction of research establishments and of their programmes.

3 The extent of present collaboration varies greatly from one university to another and depends largely on the subject matter and location. Naturally, the Arts and Social Science Departments have fewer opportunities for links with industry than the Departments of Science and Technology. Similarly,

those universities which are fortunate enough to be located close to research establishments or to major concentrations of industry have the closest links with one or other, or both, of these elements. Examples of this are London, Manchester and the Scottish Universities. On the other hand, universities such as Exeter and Keele have to go pretty far afield in order to make substantial contacts with both industry and research establishments while, in general, the universities in the North of England have fewer opportunities for contacts with research establishments than those in the South.

4 Much of the collaboration is concerned with the particular fields of research, and the contact is largely on a personal level. As one research project comes to an end and another begins, both the personalities and the nature of the contact are liable to change. The following notes, however, summarise a regular method by which the universities are at present collaborating with research establishments and industry.

PART-TIME TEACHING

5 Several universities offer 'visiting professorships' to members of research establishments. Examples of this are Imperial College, London, and the University of Strathclyde. The visiting professors are paid to give instruction; they sit on the relevant boards of study and they supervise researches for M.Sc. and Ph.D. degrees.

6 At the next level, a very considerable use is made of part-time lecturers from Establishments and from industry in the Science and Technology Departments of universities. For example, in the last session Imperial College had no fewer than 144 Visiting Lecturers—some of them gave individual lectures while others gave a series of lectures as part of the course. Bristol College of Science and Technology appear to have run them a good second; they had nearly 100 lectures from 64 different firms and research establishments—about 60% of these were from industry. Most of the other universities did not quote actual numbers, but it is clear that they do make good use of part-time lecturers in this way.

SITING OF RESEARCH ESTABLISHMENTS ALONGSIDE UNIVERSITIES

7 Collaboration between the universities and the research establishments is much easier if they are close to one another. One or two recent examples illustrate the trend in this direction. The University of East Anglia reports that the Food Research Institute and the John Innes Institute are going to be established in Norwich on land adjacent to the university and that, in each case, the Director of the Institute will serve as an ex-officio member of the Senate and will have the title of Professor. The Research Laboratory of the British Sugar Corporation is also moving to Norwich and a new building is being erected a few hundred yards from the University. It is hoped that this will lead to a very close relationship with the laboratories of the Schools of Biological Science and Chemical Science. At Bristol, the Meat Research Institute is similarly to be built alongside the Veterinary Schools Accommodation at Langford.

8 There are also examples of the universities taking into account the need for links with research establishments and industry in deciding their own location; for example, Guildford has been chosen as the new site for the Battersea College of Advanced Technology (to be re-named the University of Surrey), partly because it is within convenient reach of a number of major

Government Research Establishments (e.g. the Royal Aircraft Establishment at Farnborough) and is in an area that is well supplied with a variety of modern industries. Similarly, the decision to put the two new business schools in London and Manchester was based on the desire to have them in the closest possible contact with major concentrations of industry and commerce.

TRANSFER OF STAFF

9 There is a good deal of movement between the universities and the Research Establishments, both on permanent and temporary postings. A good example of this is Professor Edwards, who is now Chairman of the Electricity Council but who still finds time to take occasional seminars at the London School of Economics. Other examples are:—

- (i) the Principal-Elect of the University College of Swansea is at present on leave of absence, acting as Deputy Director of Research at Slough Radio Research Station;
- (ii) Swansea have an arrangement with the Steel Company of Wales Ltd., whereby a member of the staff of the Metallurgy Department is seconded to the Steel Company of Wales to work on Research Projects and 'to get the feel of' the problems currently facing the industry;
- (iii) the University of Edinburgh has an arrangement with ICI Limited, whereby a member of ICI's staff spends one term a year in the Dept. of Chemistry and participates in teaching. And the Dept. of Chemical Engineering at Edinburgh has at present a lecturer on secondment from ICI for two years.

GOVERNMENT CONTRACTS WITH THE UNIVERSITIES

10 Research contracts placed with the universities by Government Departments are often placed or monitored by research establishments. This leads to very close working relations between the two.

INSTRUCTION OF STUDENTS

11 There is some instruction of students both in establishments and in industry. For example, the National Physical Laboratory at Teddington has agreed to take some Reading students for part of their training in Physical techniques. Students of agriculture at Reading also visit the neighbouring Government Agricultural Research Institutes during their first degree courses.

12 The Sandwich Courses which are a feature of the CAT's and which the latter are determined to continue now that they have achieved university status demand the closest collaboration between the universities and industry. Not only do the students continue with their learning during their period in industry: they are also visited during this time by the staff of the university and this provides a further opportunity for personal contacts and collaboration between university staff and industry.

RESEARCH STUDENTS

13 Several of the universities already have provision for either:

- (a) Post Graduate students to carry out the whole or part of their work for Ph.D. degrees outside the university—this includes industry, as well as research establishments, or
- (b) Members of research establishments to be registered with universities as research students for the purpose of Ph.D. degrees. This is the accepted

practice at, for example, Southampton, Exeter, Strathclyde and Reading. There are, however, some difficulties over arrangements of this kind. It is essential to maintain standards and universities cannot always be satisfied that research institutions are able to design the training of Ph.D. students or to supervise their work. There are also difficulties over such students attending lectures and colloquia in the University Department. This must therefore be a slow and careful process.

CONCLUSION

14 The great majority of replies show considerable activity in collaboration between universities, research establishments and industry. Some universities which at present have no organised arrangements of this kind are considering how they could embark upon this kind of activity, while the majority of the universities which already have links with research establishments and industry are actively looking into ways and means of arranging further co-operation. Some of them have set up special committees or sub-committees for this purpose.

15 This is an encouraging picture and there is no doubt that the whole process is gathering momentum rapidly as the result of widespread interest in the support for developments of their kind. Continuous care will, of course, be needed to ensure that the arrangements in each case are soundly based and that, for example, in the use of outside lecturers and of outside facilities for training research students, proper standards are maintained.

Appendix E

Establishments

R.A.E.

R.R.E.

S.R.D.E.

S.E.R.L.

(which has inter-service responsibilities)

Neighbouring Universities

London

Oxford

Reading

Southampton

Surrey

Sussex

Birmingham

Bristol

Oxford

Warwick

Exeter

Southampton

Cambridge

Essex

London

Appendix F

Security

It is our belief that the requirements of security do not bear strongly on the educational activities of the Establishments. The rules which govern access to classified information seem to us to be sensible and to be operated with tact.

With regard to the placing of research agreements at Universities, the fact that only two or three out of some five to six hundred agreements are classified shows that university research makes almost no direct contribution to the classified part of defence research. The reluctance of university departments

to have to restrict access to part of their premises must be a discouraging factor. Similarly it is probable that some university staff would avoid defence work on conscientious grounds. However, no examples are available, partly because so little requirement for such work at universities exists and partly because the interdiction, if any, operates at a very early stage in the formulation of a proposal or requirement for research to be done.

Appendix G

Fields of technological effort in the establishments on which courses might be centred

R.A.E.

Antenna Theory and Design
Microwave Engineering
Propagation
Radar Theory and Practice
Reliability
Active Aerials
Telemetry
Air Traffic Control

R.R.E.

Solid State Device technology and design
Micro-Electronics
Advanced electronics circuit design
Laser technology
Infra-red Engineering
Design of Large Aerials
Advanced Data Handling and Computer Languages
Radar Theory and Engineering
Low Temperature Physics
Active Aerials
Range Instrumentation (satellite tracking)

S.R.D.E.

Propagation
Communications
Spectroscopy
Thin film circuits
Satellite Communication
Quantum electronics

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MINISTRY OF AVIATION

THE
EDUCATIONAL
ROLE OF THE
MINISTRY OF
AVIATION
ESTABLISHMENTS

LONDON
HER MAJESTY'S STATIONERY OFFICE
1966

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ABBREVIATIONS USED IN THE REPORT

AML	Admiralty Materials Laboratory, Holton Heath.
CAT	College of Advanced Technology.
CVD	Co-ordination of Valve Development, Ministry of Defence.
DSIR	Department of Scientific and Industrial Research.
Grad.IEE	Graduate of the Institution of Electrical Engineers.
HNC	Higher National Certificate.
ICI	Imperial Chemical Industries Ltd.
MEXE	Military Engineering Experimental Establishment, Christchurch.
MIT	Massachusetts Institute of Technology.
Portland	Admiralty Underwater Weapons Establishment, Portland.
RAE	Royal Aircraft Establishment, Farnborough, Hants.
RRE	Royal Radar Establishment, Great Malvern, Worcs.
SERL	Services Electronics Research Laboratory, Baldock, Herts.
SPSO	Senior Principal Scientific Officer.
SRC	Science Research Council.
SRDE	Signals Research and Development Establishment, Christchurch.
Winfrith	Atomic Energy Establishment, Winfrith.